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Positron probes of the Ge(1 0 0) surface: The effects of surface reconstructions and electron–positron correlations on positron trapping and annihilation characteristics

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Abstract

Positron annihilation induced Auger electron spectroscopy (PAES) has been applied to study the Ge(1 0 0) surface. The high-resolution PAES spectrum from the Ge(1 0 0) surface displays several strong Auger peaks corresponding to $M_{4,5}N_1N_{2,3}$, $M_{2,3}M_{4,5}M_{4,5}$, $M_{2,3}M_{4,5}V$ and $M_1M_{4,5}M_{4,5}$ Auger transitions. The integrated peak intensities of Auger transitions are used to obtain experimental annihilation probabilities for the Ge 3d and 3p core level electrons. These experimental results are analyzed by performing calculations of positron surface states and annihilation characteristics of surface trapped positrons with relevant Ge core-level electrons for the nonreconstructed and reconstructed Ge(1 0 0)-p(2×1), Ge(1 0 0)-p(2×2) and Ge(1 0 0)-c(4×2) surfaces. It is found that the positron surface state wave function extends into the Ge lattice in the regions where atoms are displaced from their ideal terminated positions due to reconstructions. Estimates of the positron binding energy and the positron annihilation characteristics reveal their sensitivity to the specific atomic structure of the topmost layers of Ge(1 0 0). A comparison with PAES data reveals an agreement with theoretical core annihilation probabilities for the Auger transitions considered.

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1. Introduction

The annihilation characteristics of low energy positrons trapped at metal and semiconductor surfaces are of interest because of the possibilities of using positrons in the development of new probes of surfaces, thin films and nanostructures. In addition, the annihilation characteristics provide a means of studying fundamental questions related to the nature of positron surface states, which are examples of "quasi-two-dimensional" states of distinguishable, light, quantum particles. Recently positron annihilation induced Auger electron spectroscopy (PAES) has been applied to study the nature and localization of positron bound states at metal and semiconductor surfaces, both clean and adsorbate-covered [1,2]. In PAES experiments most of the low energy positrons, implanted into the sample under study, diffuse back to the vacuum–solid interface where on the order of half are trapped into a surface state. A certain fraction of the surface trapped positrons annihilates with neighboring core level electrons, creating core-hole excitations that give rise to Auger-electron emission. The intensities of the measured positron annihilation induced Auger signals are sensitive to the spatial distribution of the positron wave function on the surface and are directly related

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